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Spanish method of visual impact evaluation in wind farms

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Abstract

The present Spanish laws on the procedure to evaluate the environmental impact of wind farms are ambiguous, especially those pertaining to visual impact. There is no specific national law but only regional laws. The main targets of these laws are the conservation of the environment (protected animals and plants), and the noise generated. The focus of this paper, the visual impact, is not taken into account in a direct way in these laws.

This work develops a methodology to predict, before its construction, the visual impact that a wind farm can have. This could be used as a consulting tool to analyze and evaluate wind projects, both government-run and private.

The developed methodology is quick, concise and clear.

Keywords: Environment impact; Visual impact evaluation matrix; Wind farm

Contents

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1. Introduction

The increase in energy demand and the minimum quote (12%) for renewable energy sources established by the White Book of the European Union in 2010 are the main reasons for the construction of wind farms. Nowadays, this kind of energy represents about 7% of the electricity generated in Spain. Wind farms produce very low pollution, although they can be annoying for people who live in the vicinity, mainly due to blade noise and visual landscape modification.

Specific rules for the installation of wind farms are there for each Spanish region, but these rules take into account mainly the conservation of the environment (protected animals and plants), and the noise generated [1–6]. Furthermore, there is a national law regarding noise [7]. There is no specific norm for regulating visual impact.

The appreciation of visual impact is a subjective topic, and the law must be clear, objective and concise to be able to measure it.

A classical methodology consists of drawing radial profiles from the top of each tower. If the population core remains under this line with respect to the topographical level, the wind farm is not seen from the village. In this way, the village is fully affected or not, depending on the village core.

The proposed methodology takes into account different village areas, and the village can be partially affected as well.

This methodology carries out a 3D analysis of the wind farm and its surrounding area to obtain simulated images from the village area that is potentially affected. Subsequently, a visual impact evaluation matrix (VIEM) applied over the neighboring villages of the wind farm is obtained. Thus, it can evaluate the possibility of total or partial installation of a wind farm.

2. Data preparation

An accurate way of evaluation is through geographical map information, in digital format. Thus, one can see the wind farm with its real dimensions in a 3D lay-

out. The accuracy is proportional to the scale of resolution used. In this work, a software based on a geographical information system (GIS) is used to obtain a solid 3D view from a digital geographical map, with a scale of 1:5000. Previously, the map is treated by means of a CAD software.

The process comprises several steps, beginning with the preparation of the original file. In this file, interest layers are filtered using CAD programs. Then, by means of GIS software, the files are imported, previously separated by layers, and they are transformed into the graphic format of the GIS software (Fig. 1). After that, creation of the topographical solid surface, showing the necessary layers (roads, buildings, forests, etc.), proceeds (Fig. 2).

The next step consists of introducing the tower measure of the windmills, assigning a height and altitude (to intercept the solid topographical surface, Fig. 3). Also, 3D objects can be added, for example, blades and nacelles of the windmills, previously drafted by means of CAD software.

Once all files are prepared, different views or visuals that are desired are obtained, capturing the necessary images for subsequent evaluation. Thus, a video sequence can be obtained by means of some image management software that permits one to obtain a series of ordered images.

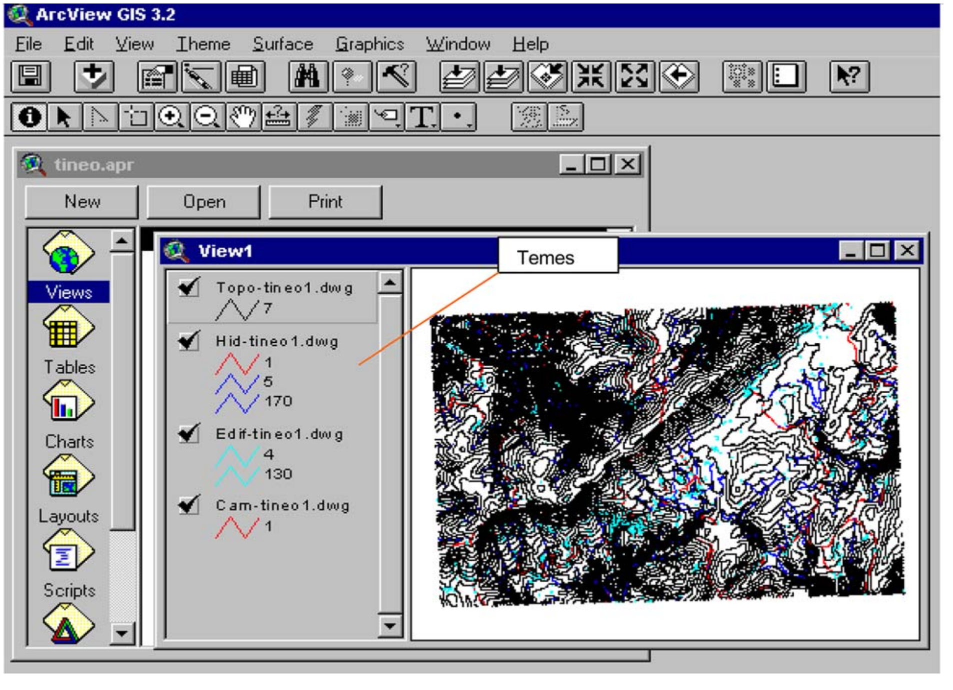


Fig. 1. Operation of GIS software to import the CAD file.

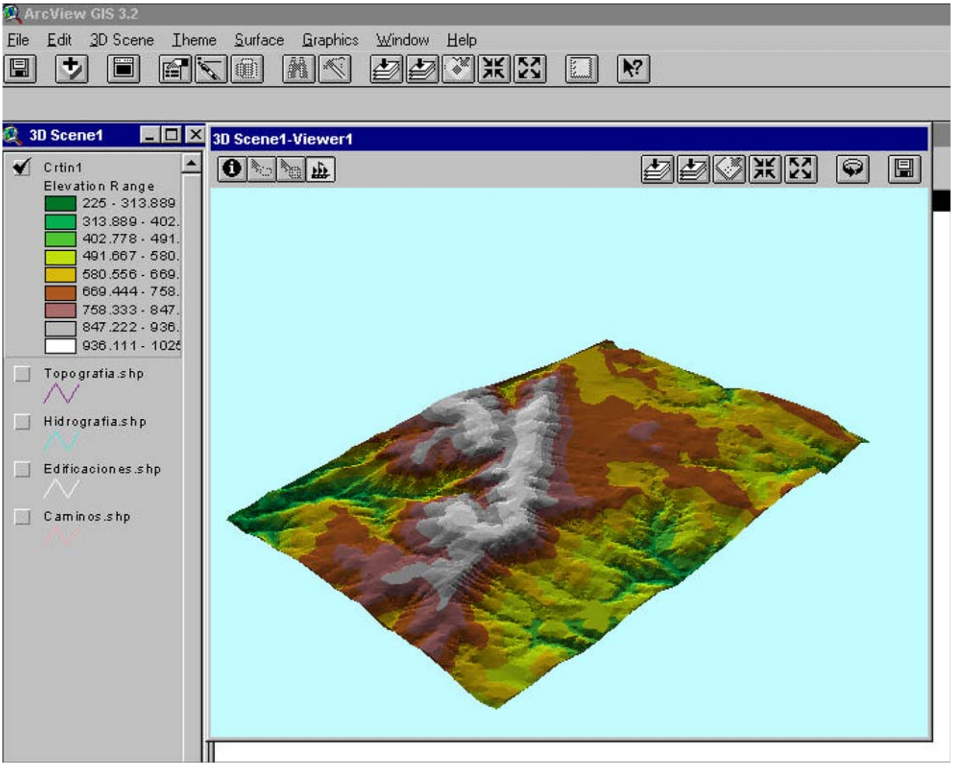


Fig. 2. Topographical solid surface after creation.

3. Visual impact evaluation matrix (VIEM)

Once the 3D maps of wind farm area are obtained, we proceed to calculate the visual impact evaluation matrix (VIEM), this being necessary to know the different affected types in the village (coefficients).

3.1. Visibility coefficient of wind farm from village (*a*)

The village is split into several areas to determine this coefficient. If the visual impact varies inside the village, this coefficient will be an approximation to a medium value. The way to calculate this coefficient is by the expression

$$a = \frac{\sum_{i=1}^{n} X_i/WM}{n}$$

where n is the number of areas inside the village with different views of the wind farm, X_i is the number of windmills visible from area i, and WM is the total number of windmills in the wind farm.

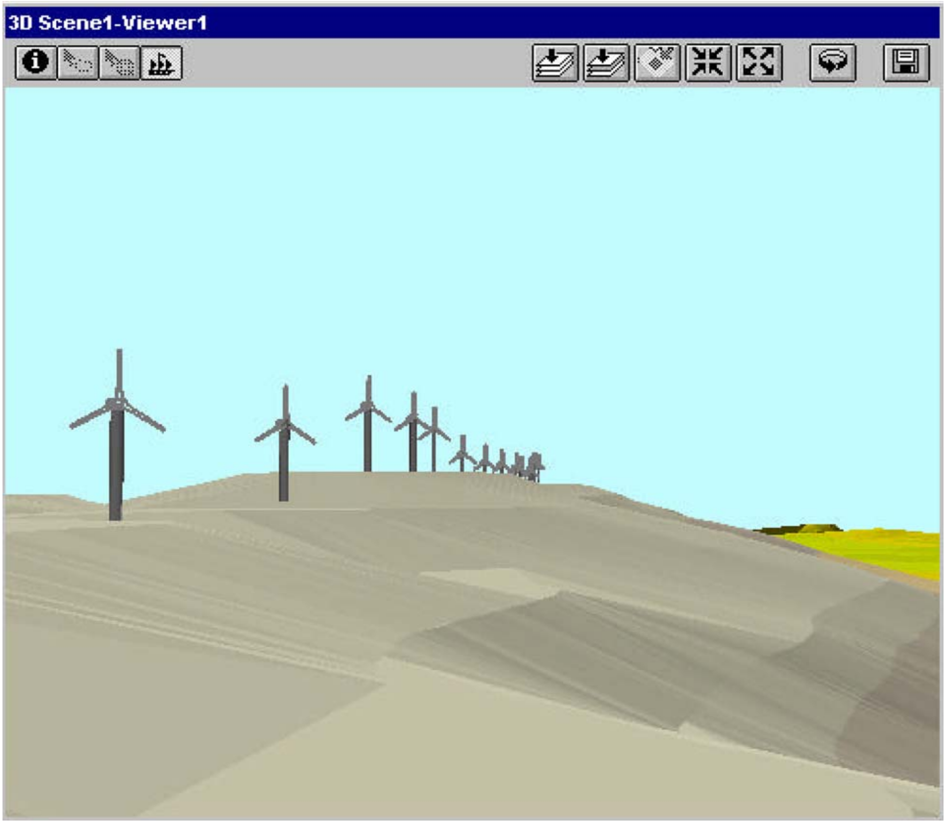


Fig. 3. 3D view of the wind farm.

3.2. Visibility coefficient of village from wind farm (*b*)

This measures the number of houses visible from the wind farm (from each windmill), from among the total number of houses of the village. This coefficient is not dependent on the previous one.

$$b = \text{number of houses visible from the wind farm/total number of houses in the village}$$

3.3. Visibility coefficient of the wind farm taken as a cuboid (*c*)

The wind farm can be visualized inside a cuboid of regular shape (Fig. 4a). This enables one to say that the wind farm could be seen from the front, diagonally or longitudinally (Figs. 4b–d and 5), depending on the side of viewing. Thus, a factor v can be assigned for evaluation inside the matrix VIEM (Table 1). Also, there is a direct relation with the number of windmills belonging to the wind farm, because

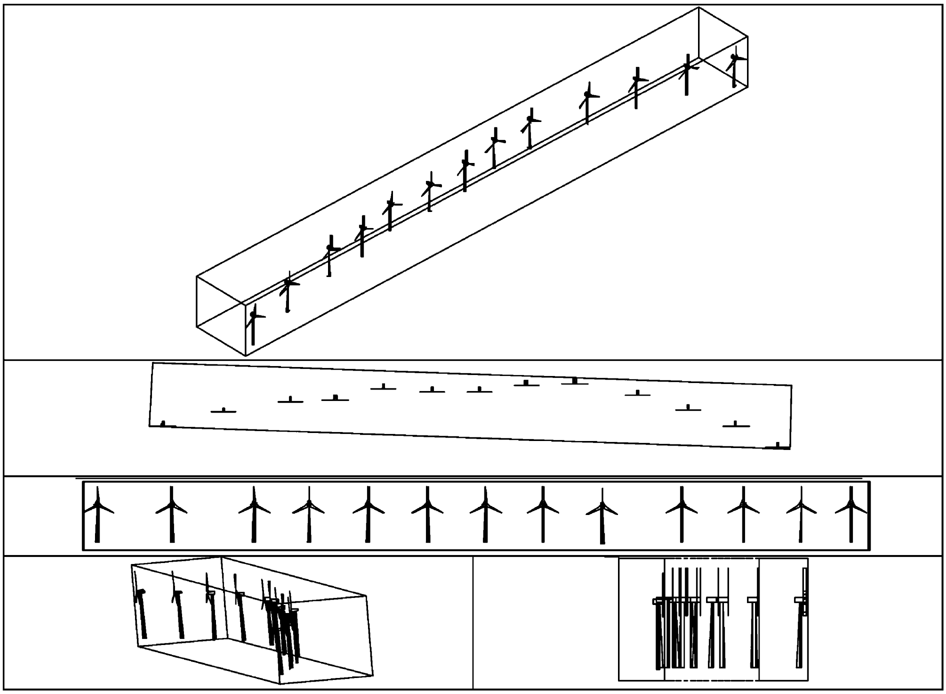


Fig. 4. Wind farm views (a: 3D, b: aerial, c: front; d: diagonal, e: longitudinal).

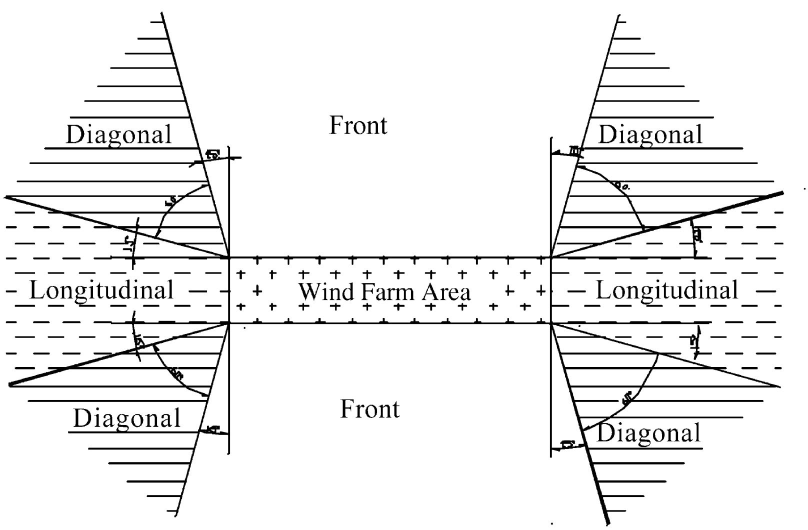


Fig. 5. Points of view.

Table 1
Correction factor function of the situation

View	v factor
Frontal	1.00
Diagonal	0.50
Longitudinal	0.20

including three windmills is not the same as including 25. For that, a quantity factor n is added (Table 2).

With these two values, the visibility coefficient can be calculated:

$$c = v * n$$

3.4. Distance coefficient between the wind farm and the village (d)

This takes into account the distance between the wind farm and the village. The distance to each village or its proximity to the wind farm is directly proportional to the alteration in the landscape. A visual influence radius is assigned to each windmill and a coefficient as well. For distances greater than 6000 m, and while the wind farm is still visible, the associated impact will be minimum; the wind farm could be considered as part of the background landscape (Table 3).

3.5. Population coefficient of the village

The visual impact increases when the number of people increases in the village, this coefficient being maximum in highly populated areas, like towns (Table 4).

Table 2
Correction factor function of the number of windmills

Number of windmills	n factor
1–3	0.50
4–10	0.90
11–20	1.00
21–30	1.05
>30	1.10

Table 3
Coefficient function of the distance

x distance	d coefficient
$x < 500$ m	1.00
$500 < x < 6000$ m	$1.05–0.0002 * x$
6000 m $< x$ (if WF visible)	0.10

Table 4
Coefficient function of the number of people

Number of people	*e* coefficient
>300	1.00
100–300	0.90
50–100	0.60
20–50	0.45
5–20	0.35
1–5	0.20
0	0.00

4. Evaluation

4.1. Partial assessment 1 (PA1)

$$PA1 = a * b * c * d$$

This allows one to obtain a factor between 0.00 and 1.00 that would correspond to the visual impact level generated for each village.

4.2. Partial assessment 2 (PA2)

$$PA2 = a * b * c * d * e$$

It is identical to the previous one except that the village and the town are not the same importance and then, a population coefficient (e) is added.

In this way, with these values, PA1 or PA2, the visual impact level can be found in the Table 5.

(a) Minimum impact: the installation of the wind farm does not have any impact.
(b) Light impact: a decrease in the impact by means of wind farm camouflage (for example, color and/or vegetation) is recommended.
(c) Medium impact: efforts should be made to diminish the visual impact, by relocating some of the towers that are closer to habitation.
(d) Serious impact: part or whole of the location of the wind farm should be corrected.

Table 5
Determination of the impact level

Partial assessment	Impact level
0.00–0.10	Minimum
0.10–0.30	Light
0.30–0.50	Medium
0.50–0.70	Serious
0.70–0.90	Very serious
0.90–1.00	Deep

(e) Very serious impact: the location of the wind farm should be revised and corrected in part or in total, trying to change its place.
(f) Deep impact: there are no justifiable reasons for carrying out the installation of the wind farm.

4.3. Total

The total evaluation is the coefficient of the population that would be permanently affected by the view of the wind farm, divided by the total number of people in the area analyzed:

$$C = \sum_{i=1}^{m} \frac{a * b * (NH_m)}{(NTHE)}$$

where C is the total coefficient of affected people, NH_m is the population of village m, $NTHE$ is the total number of people in the area analyzed, a is the visibility coefficient of the wind farm from the village and b is the visibility coefficient of the village from the wind farm.

5. Conclusions

The visual impact evaluation method proposed is a clear and objective method of assessment that allows one to quantify the visual impact generated by a wind farm in the affected neighboring population. It is supported by means of a graphic design tool based on a geographical information system (GIS) that permits one to build a 3D map of the area.

In this way, this methodology could be used as a consulting tool by both government and private companies to evaluate the effect of the installation of wind farms.

Acknowledgements

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